

ON LARGE- p_T DIRECT PHOTONS, MESONS, k_T , AND THE GLUON DISTRIBUTION

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For the Fermilab E706 Collaboration

DAVIS * DELHI * FERMILAB * MICHIGAN STATE * NORTHEASTERN
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1. Introduction

2. Investigating k_T in E706

- $\gamma\gamma$, $\pi^0\pi^0$ and γ -jet distributions
- π^0 and $D^\perp p_T$ distributions

3. E706 π^0 s and direct photons vs pQCD

- Cross section data for:

- $\heartsuit \pi^-Be \rightarrow \gamma, \pi^0 X$ at 515 GeV/c
- $\heartsuit pBe \rightarrow \gamma, \pi^0 X$ at 530 and 800 GeV/c

- QCD scales
- k_T smearing

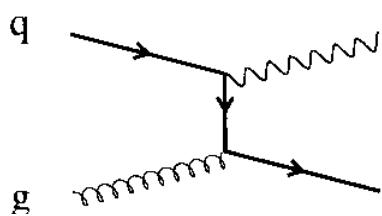
4. Investigating the gluon

- Gluon fit results
- Comparisons to E706 direct photon and collider jet data

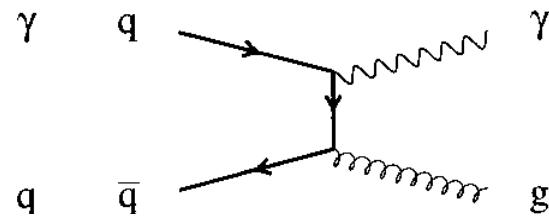
5. Summary

GOALS

- Direct photon production is sensitive to the gluon distribution.



Compton Diagram



Annihilation Diagram

- E706 obtained high statistics measurements of large- p_T production of direct photons and neutral mesons (π^0, η, ω).

Beams	Targets	Energy (GeV)	p_T (GeV)	x
p, π^-	p, Be, Cu	515, 530, 800	3.5–12	0.2–0.7

- NLL pQCD calculations exist for both direct photon and meson inclusive cross sections; π^0 and η fragmentation functions are available.
- E706 data test the calculations and can constrain parton distribution and fragmentation functions.

ABOUT k_T EFFECTS

- k_T refers to the transverse momenta of partons in colliding particles before the hard scattering.
- Average $\langle k_T \rangle$ values significantly larger than expected from non-perturbative hadron-size effects have been observed in dimuon and diphoton production, and have been interpreted as resulting from multiple soft gluon emissions.
- Current NLL calculations of inclusive large- p_T photon and light hadron production neglect such soft gluon effects.
- In our data, transverse motion of partons manifests itself through the kinematics of the hard-scattering events ($\gamma\gamma$, γ -jet, $\pi^0\pi^0$ pairs):
 - out-of-plane momentum (P_{out})
 - transverse momentum of the pair ($|\vec{P}_{T_1} + \vec{P}_{T_2}|$)
- k_T is expected to modify
 - the magnitude and shape of steeply falling high- p_T inclusive cross sections
 - fragmentation distributions observed in jets recoiling against high p_T triggers

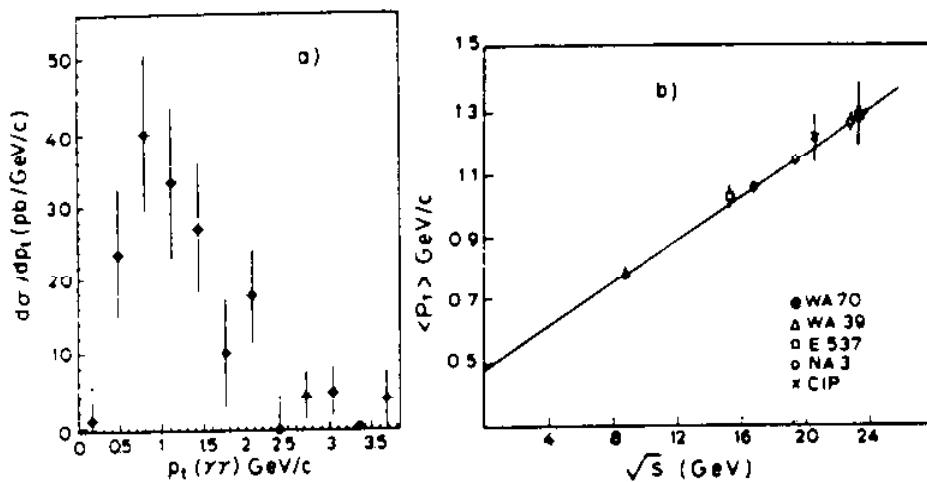


Fig. 2. (a) The differential cross section of the reaction $\pi^- p \rightarrow \gamma\gamma X$ as a function of the p_t of the $\gamma\gamma$ pair. The data are integrated over p_t , from $p_{t1} = 3.0$ GeV/c and $p_{t2} = 2.75$ GeV/c and over the full rapidity range. The error bars include the statistical uncertainties of the data and of the Monte Carlo's. (b) The mean p_t of the $\gamma\gamma$ pair compared to the mean p_t of the lepton pair measured in the reaction $\pi^- N \rightarrow \mu^+ \mu^- X$ by various Drell-Yan experiments. The line is the fit from ref. [7] described in the text.

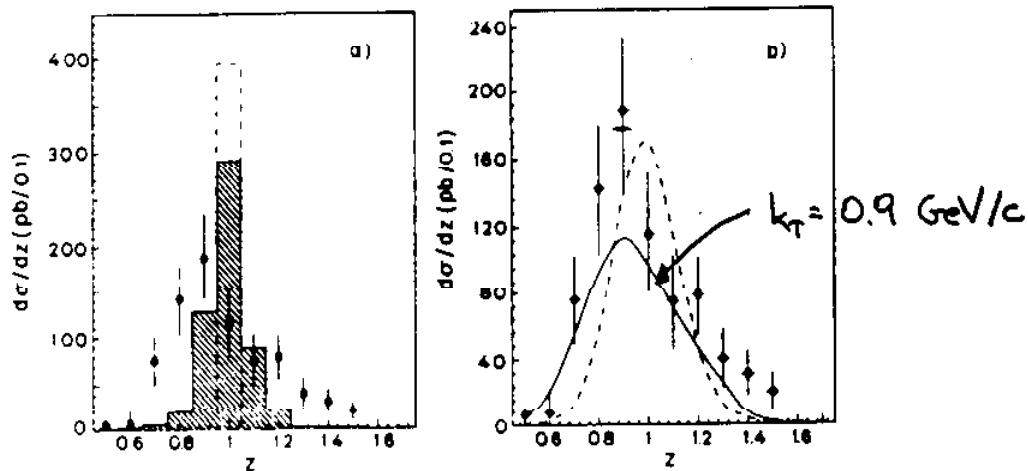
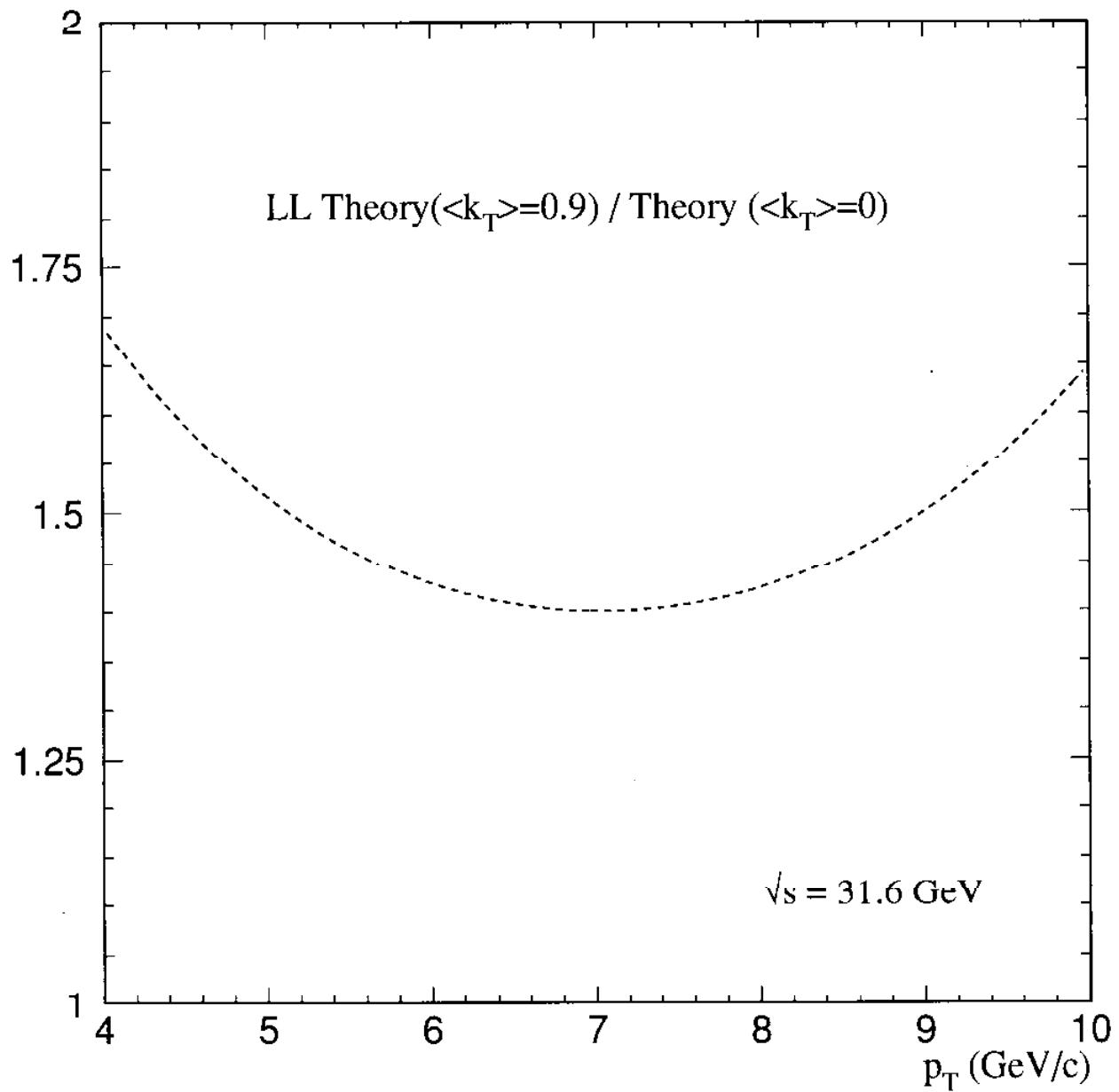
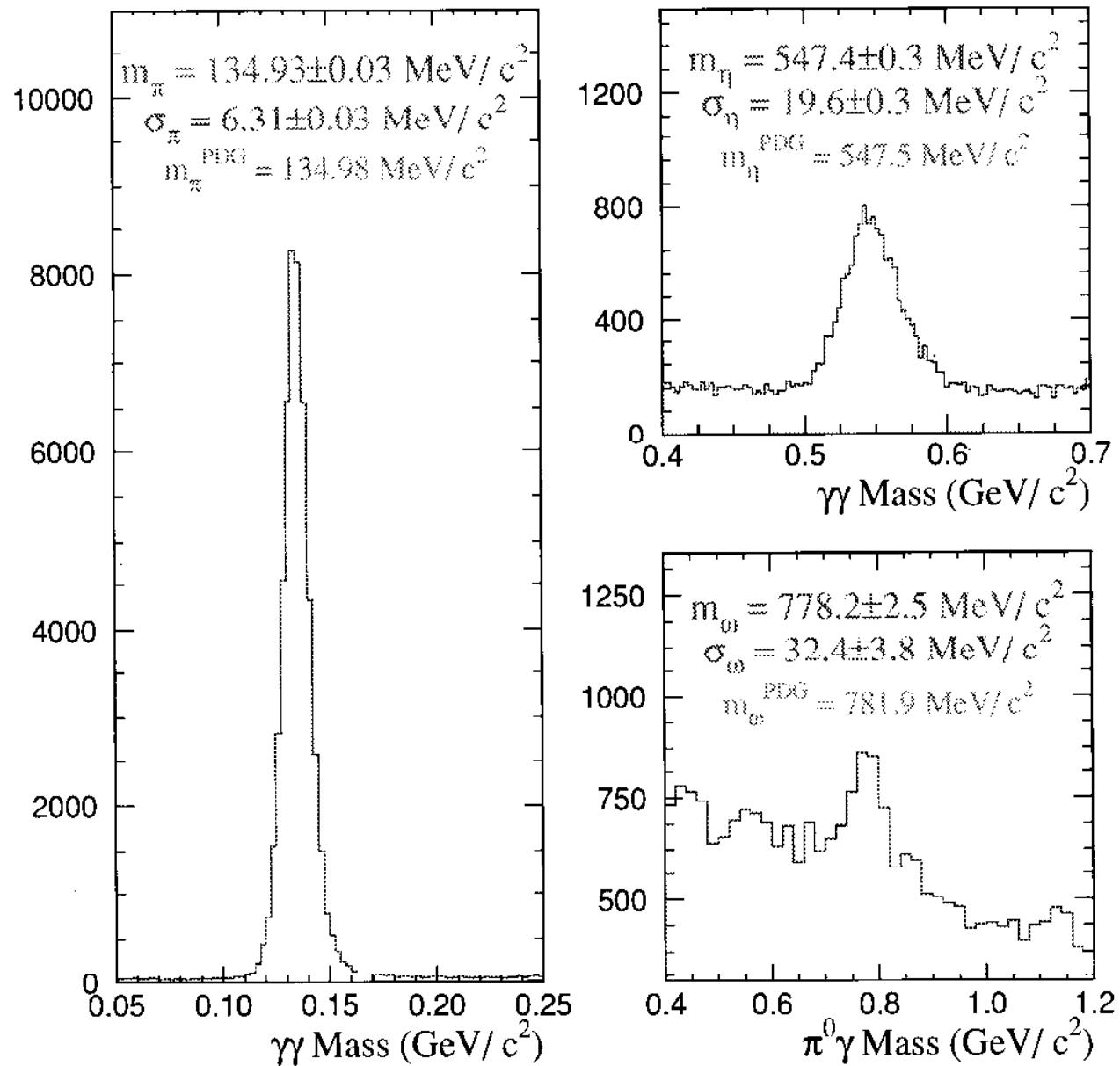


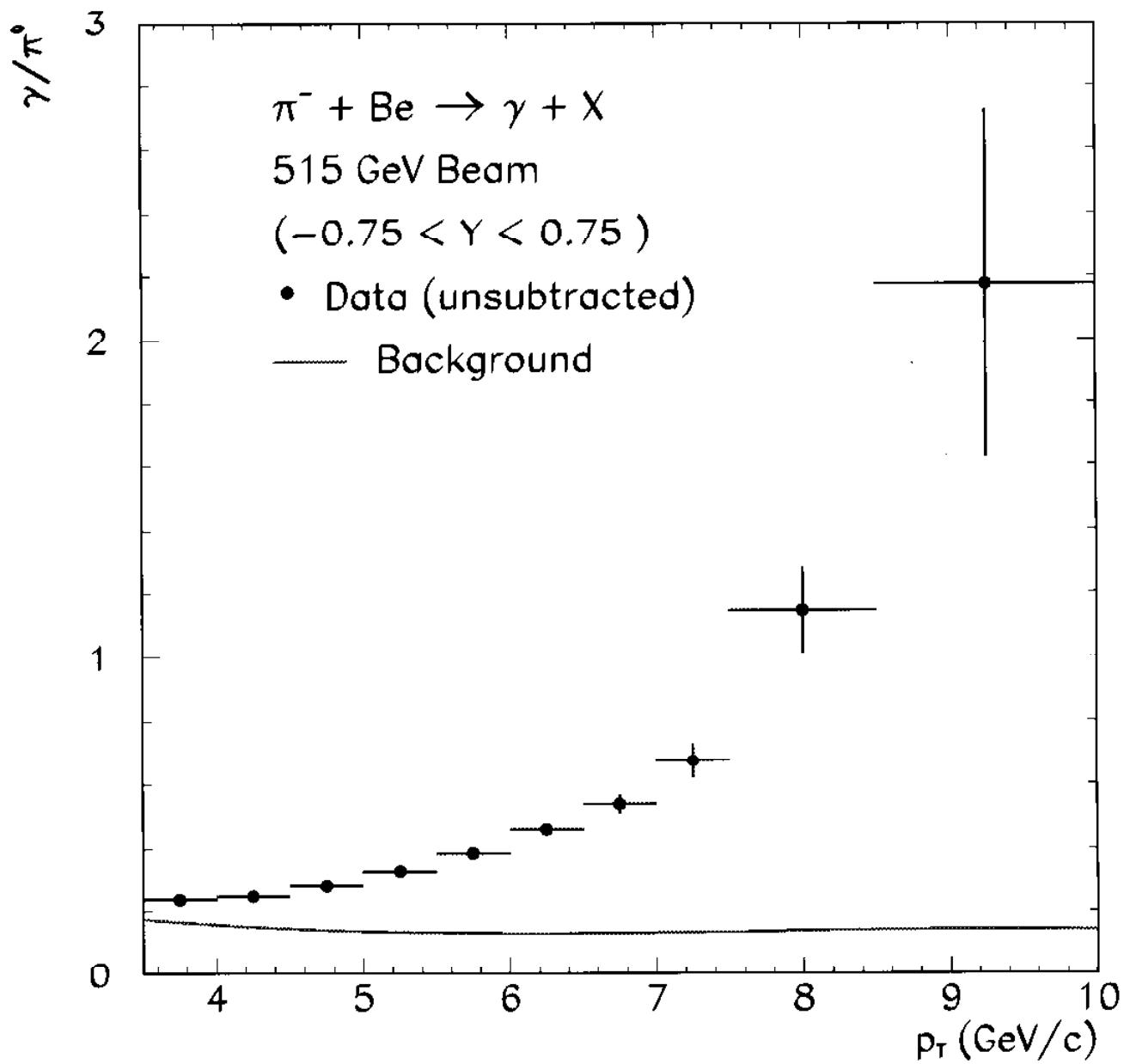
Fig. 3. The differential cross section of the reaction $\pi^- p \rightarrow \gamma\gamma X$ as function of the z variable. The data are integrated over the full rapidity range, and over p_t , from $p_{t1} = 3$ GeV/c. For each γ entering the histogram a cut $z > 2.75/p_t$ is applied. The error bars are the statistical uncertainties of the data and of the Monte Carlo's. (a) The leading order $q\bar{q} \rightarrow \gamma\gamma$ prediction (broken line) and the BLL QCD calculations [2] (shaded area) are indicated. (b) The BLL calculations widened by an intrinsic transverse momentum $\langle k_t \rangle = 0.34$ GeV/c (dashed line) and by $\langle k_t \rangle = 0.9$ GeV/c (continuous line) are superimposed on the data.

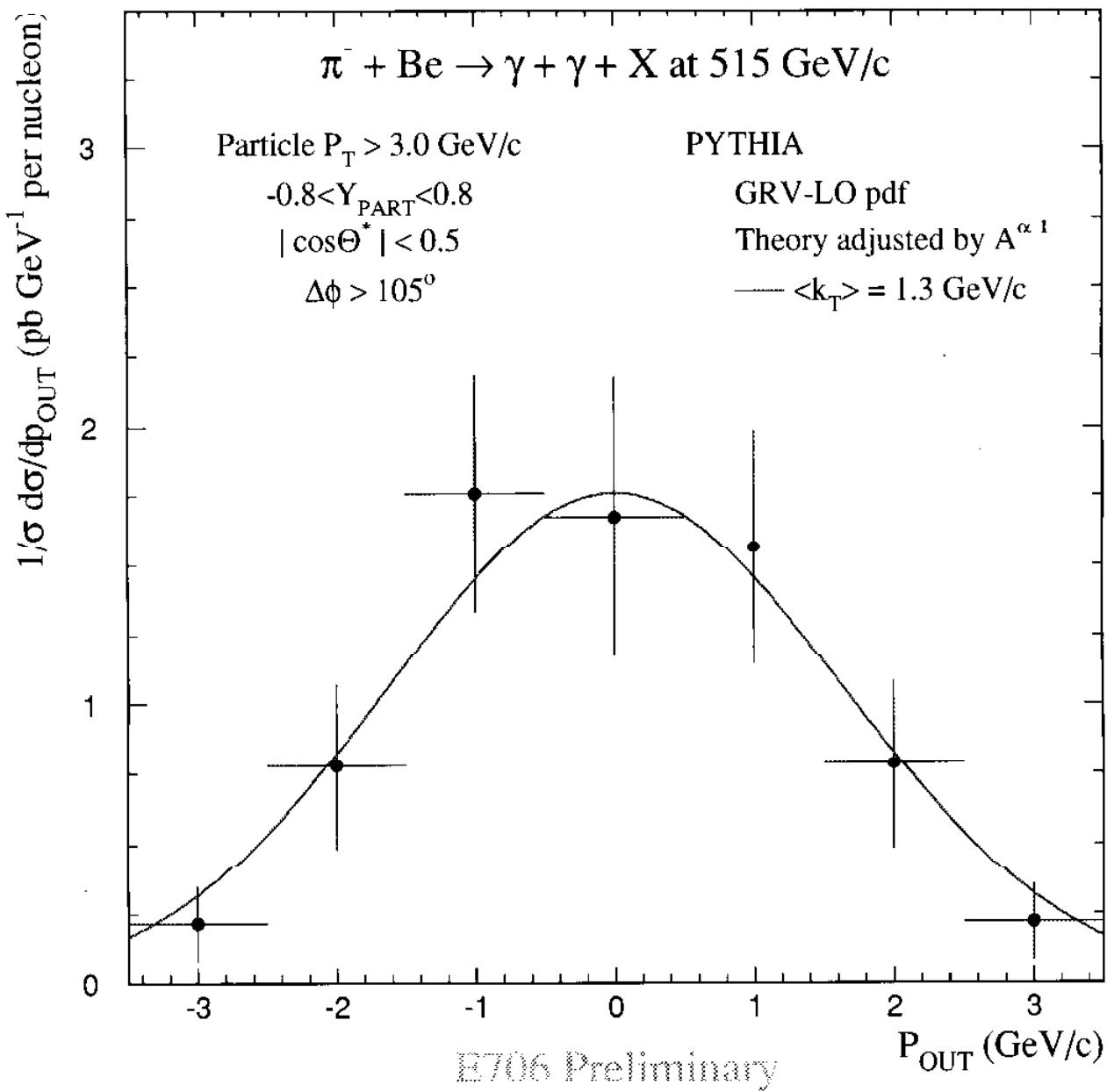
$$z = -\vec{p}_{T\gamma_1} \cdot \vec{p}_{T\gamma_2} / |\vec{p}_{T\gamma_1}|^2$$

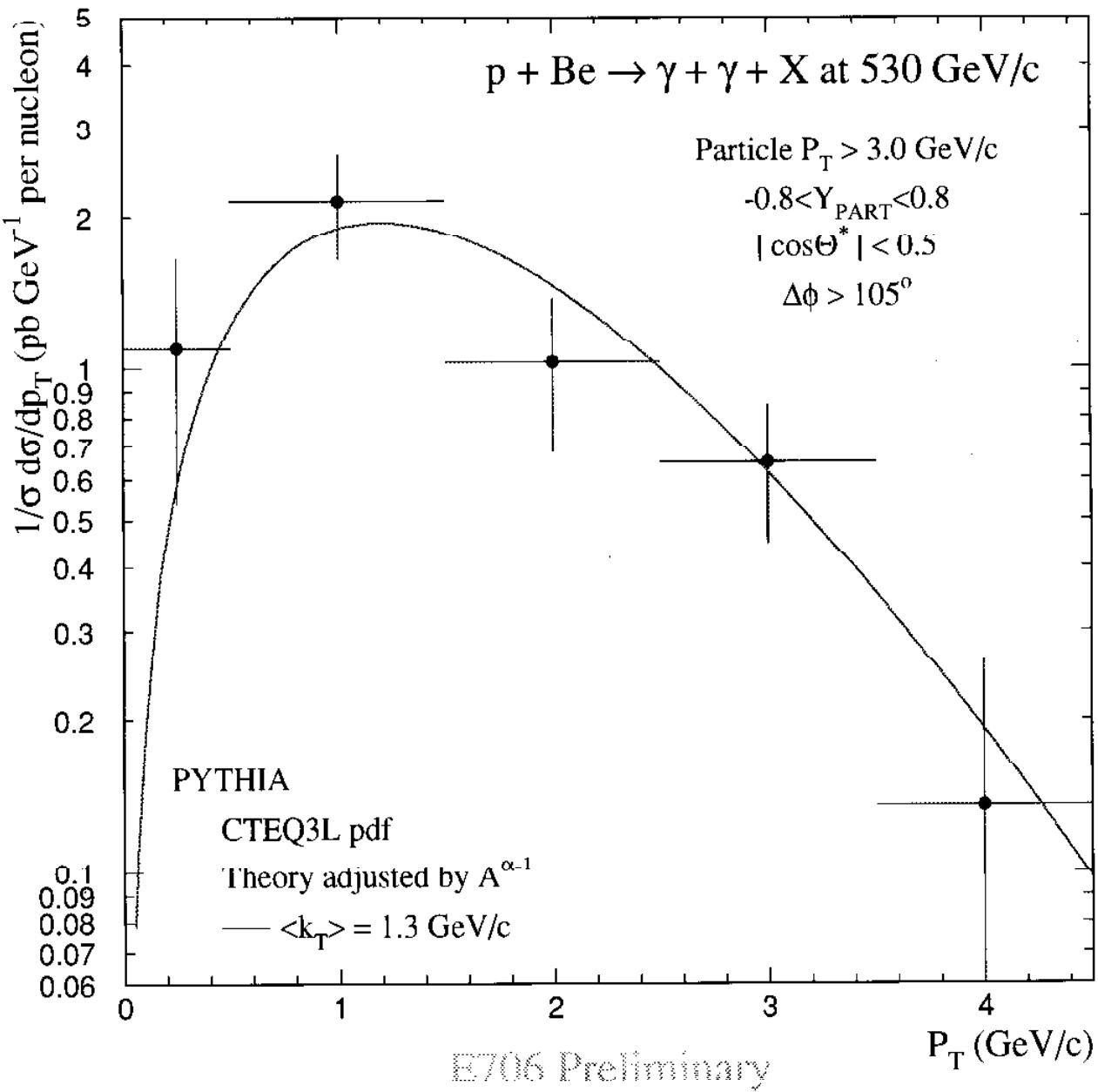


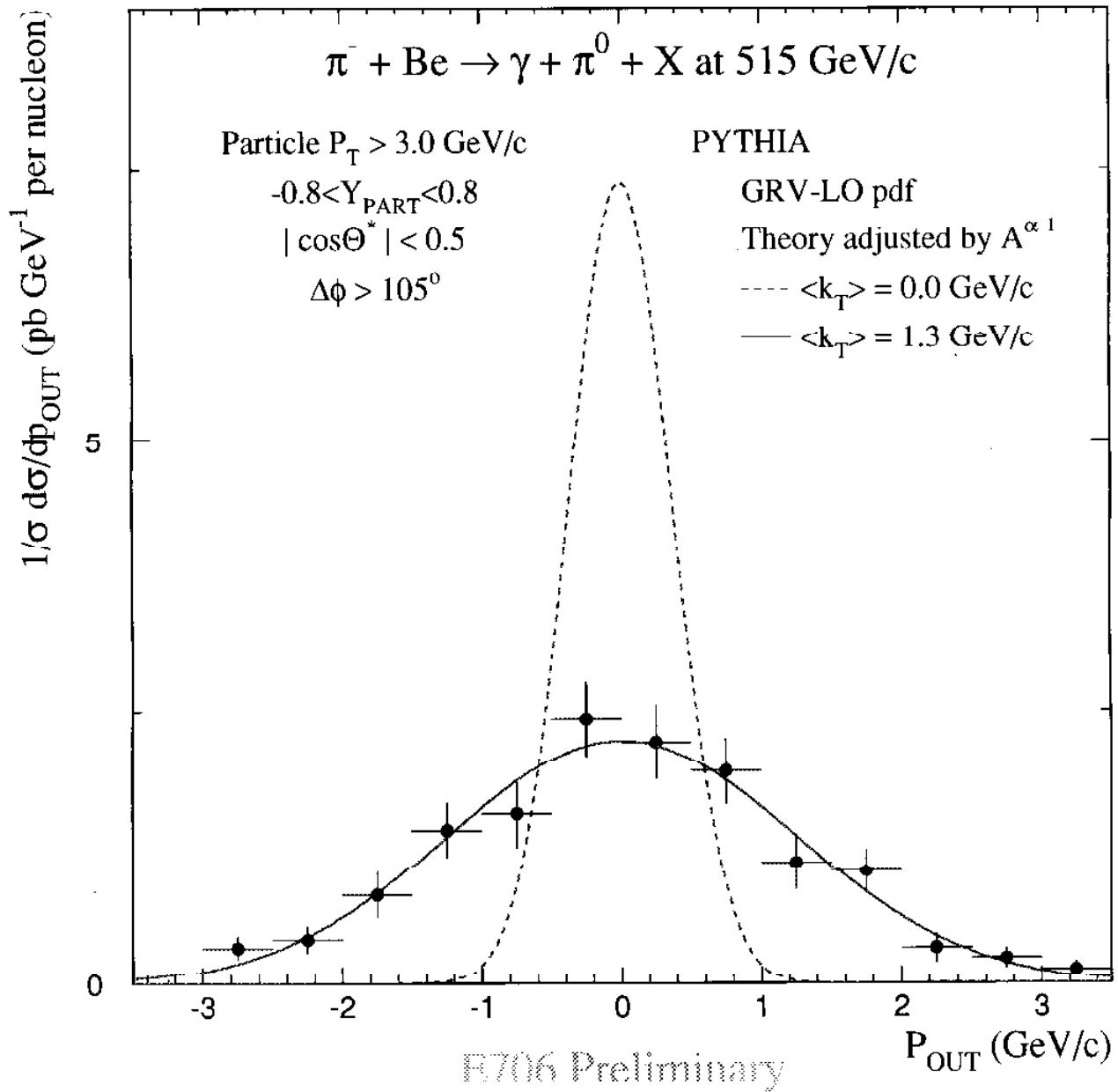
Meson Signals ($P_T > 5 \text{ GeV}/c$)

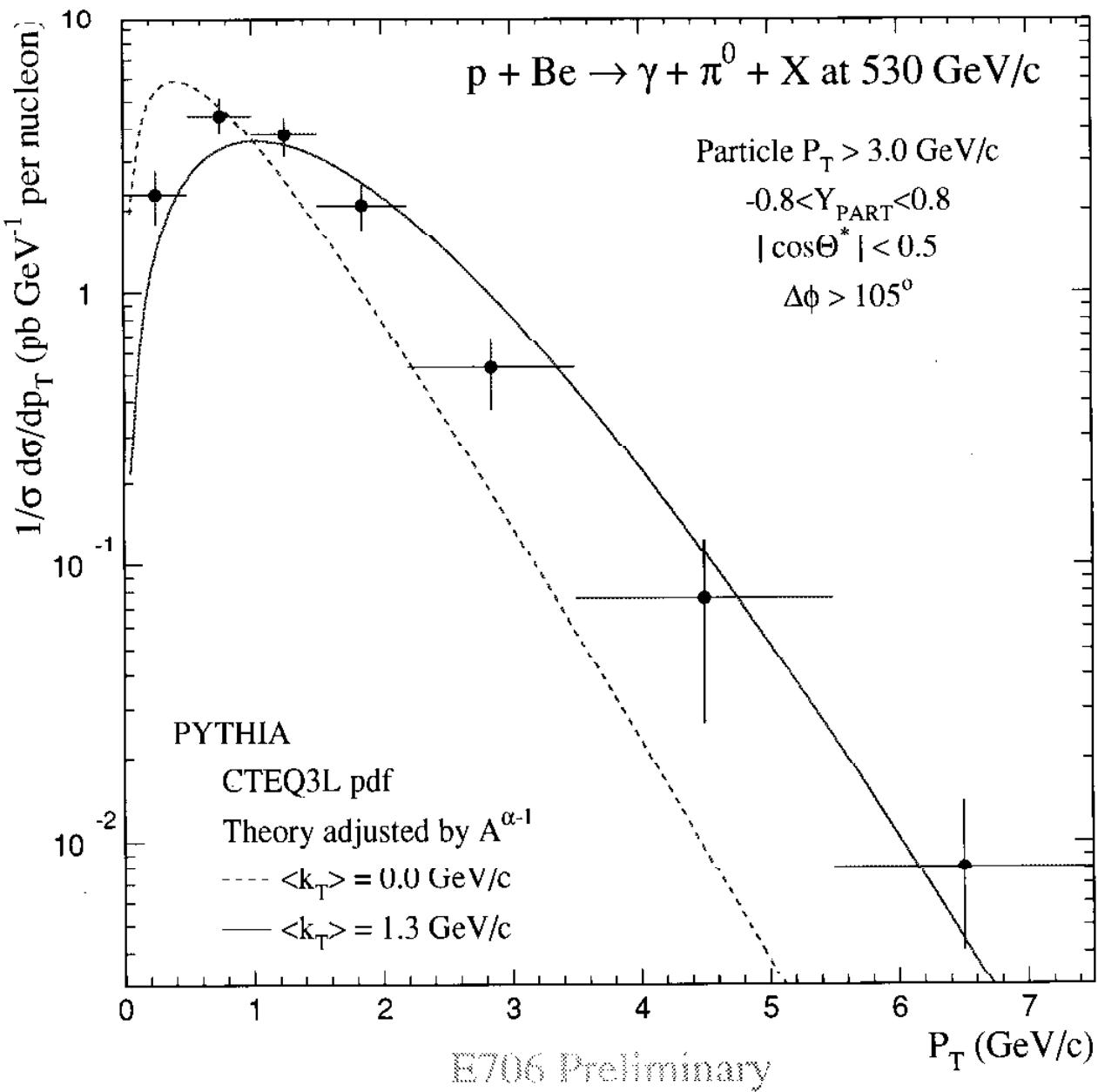


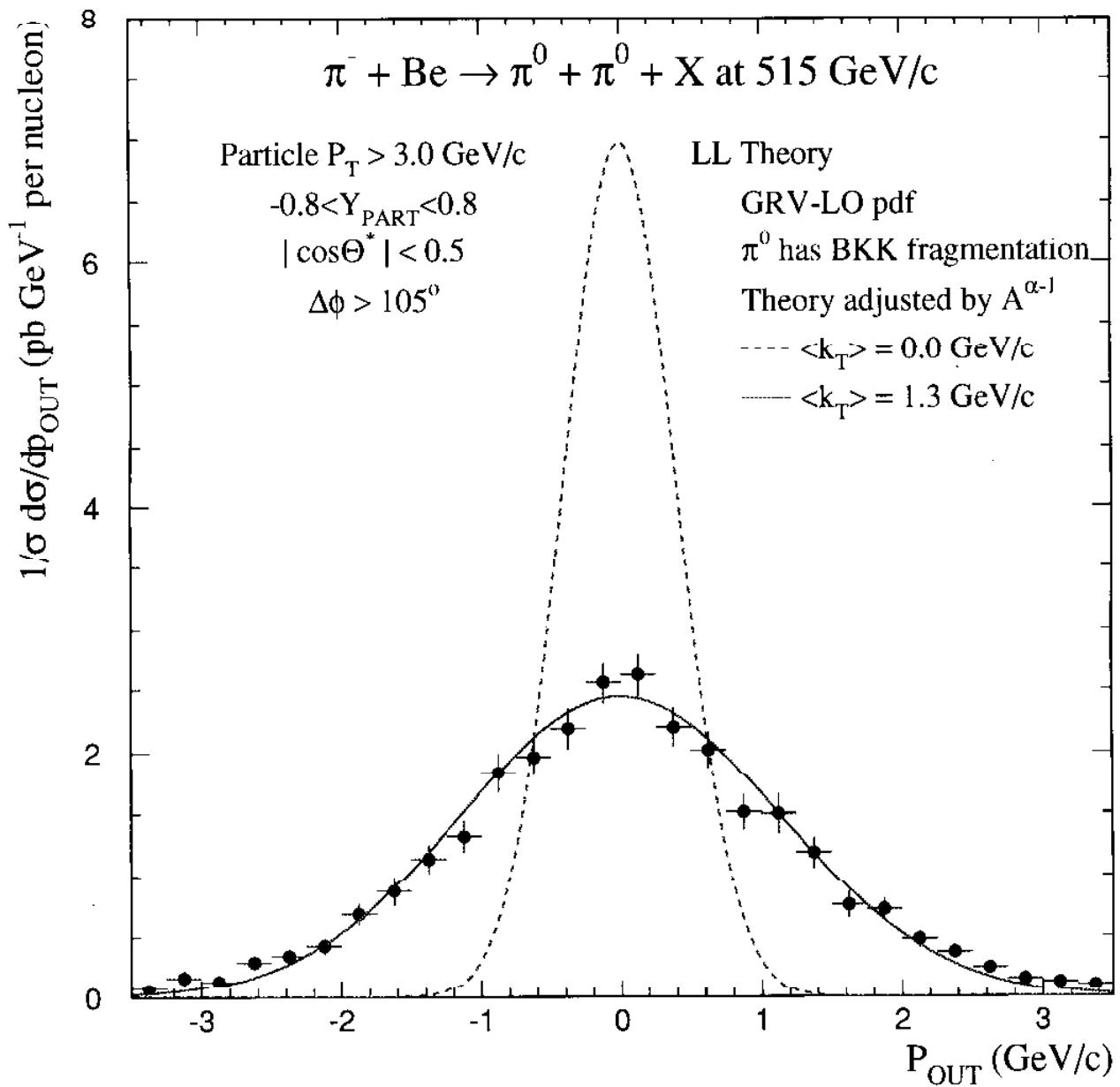


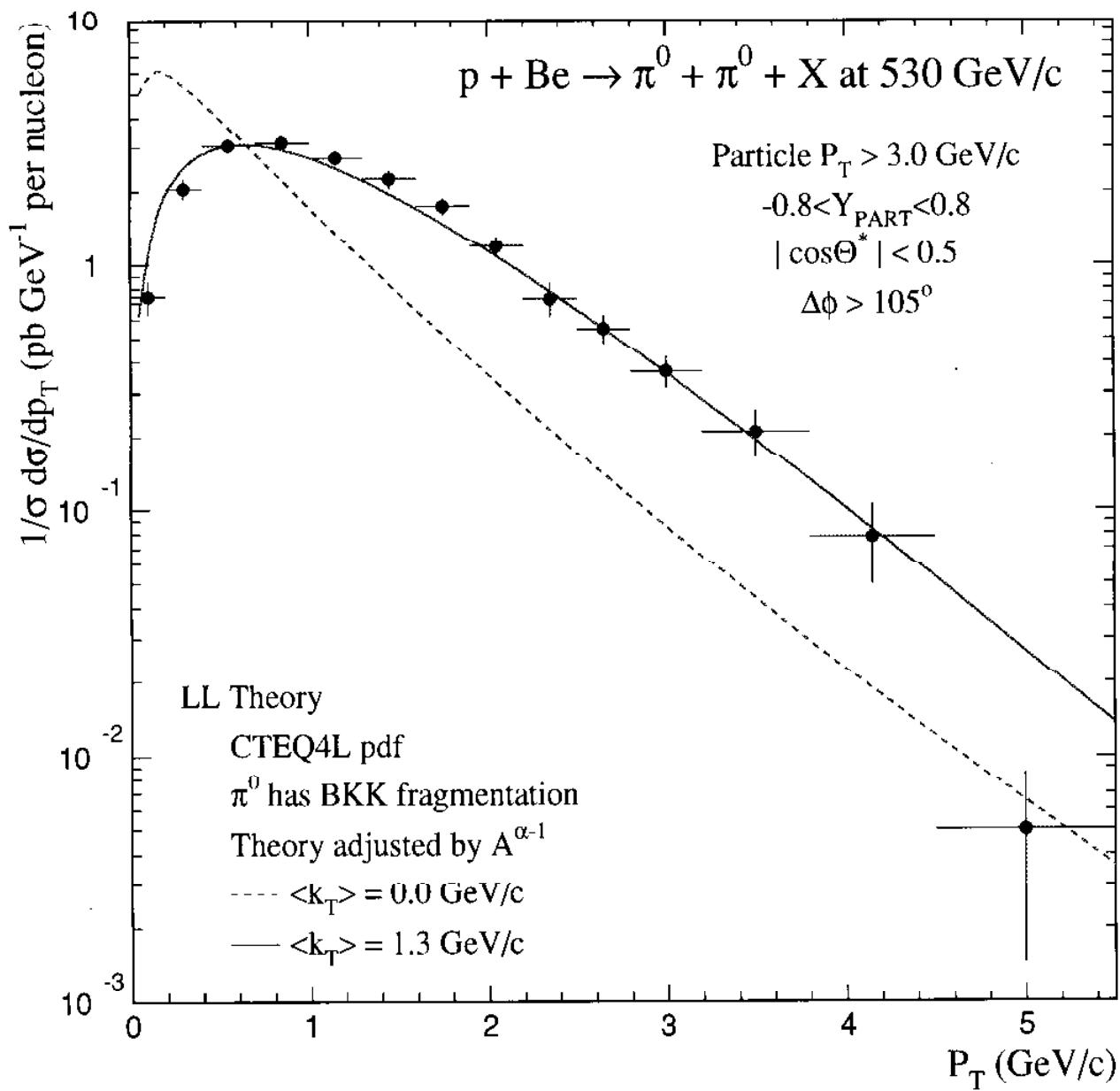




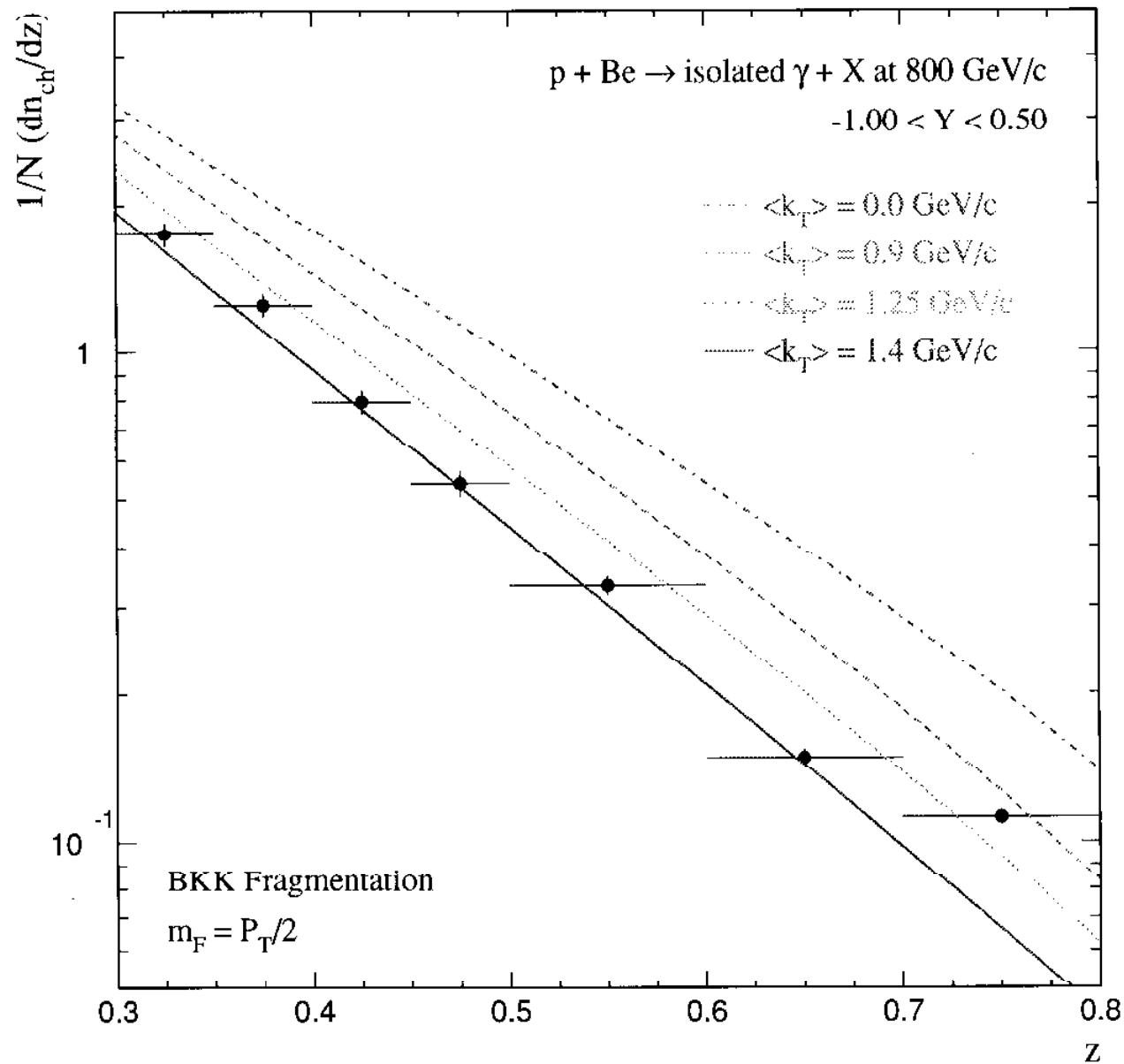


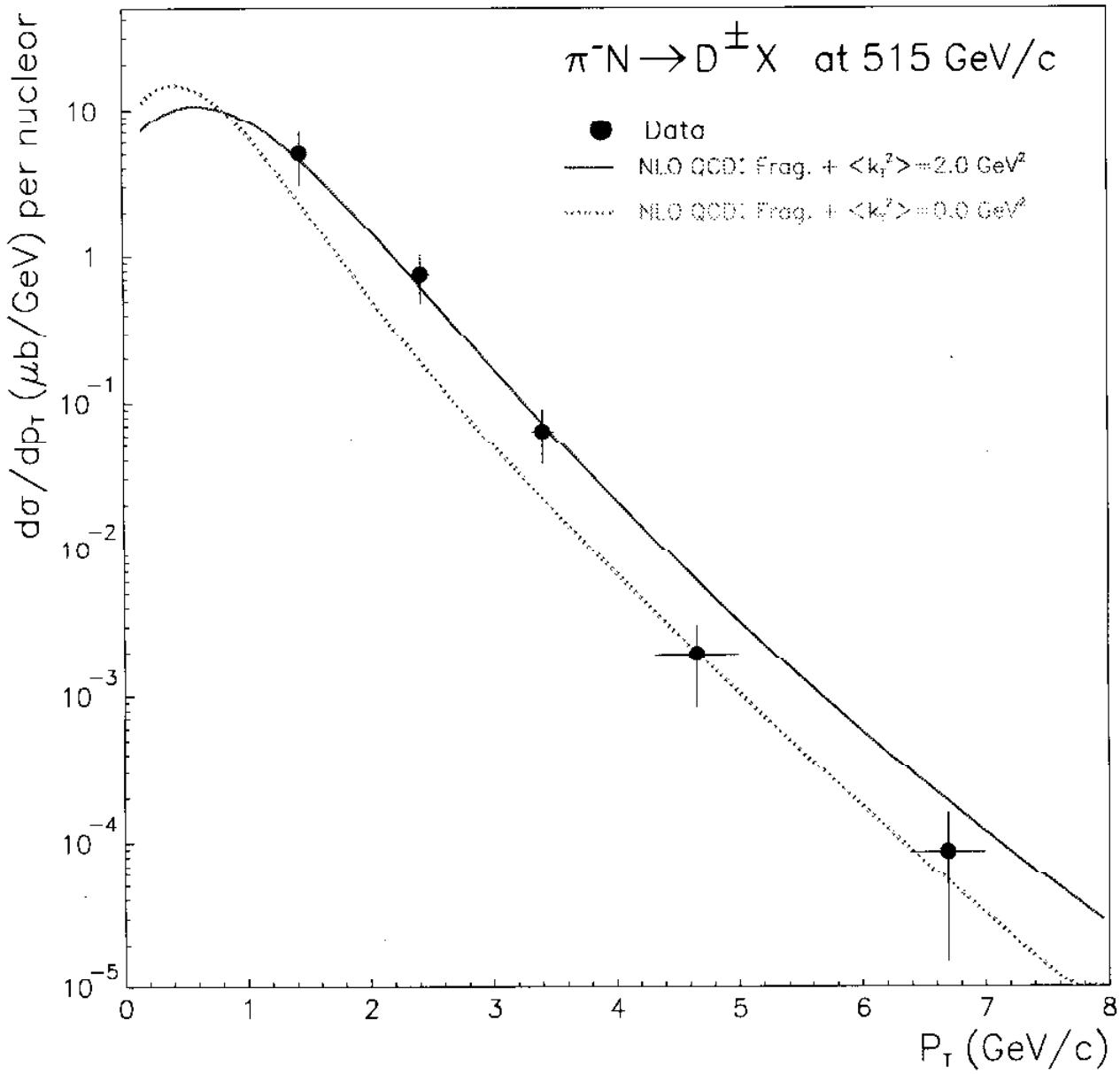


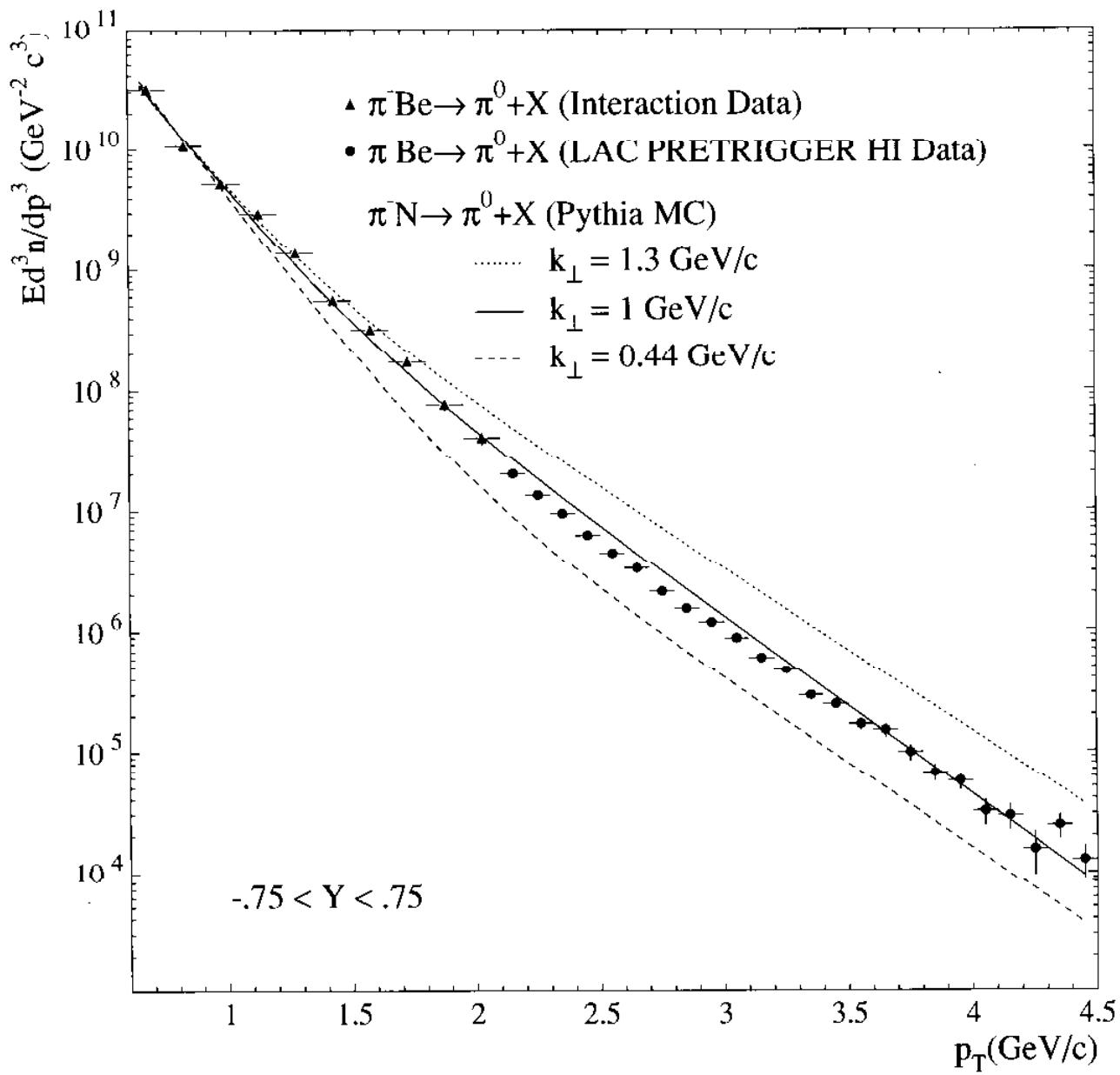




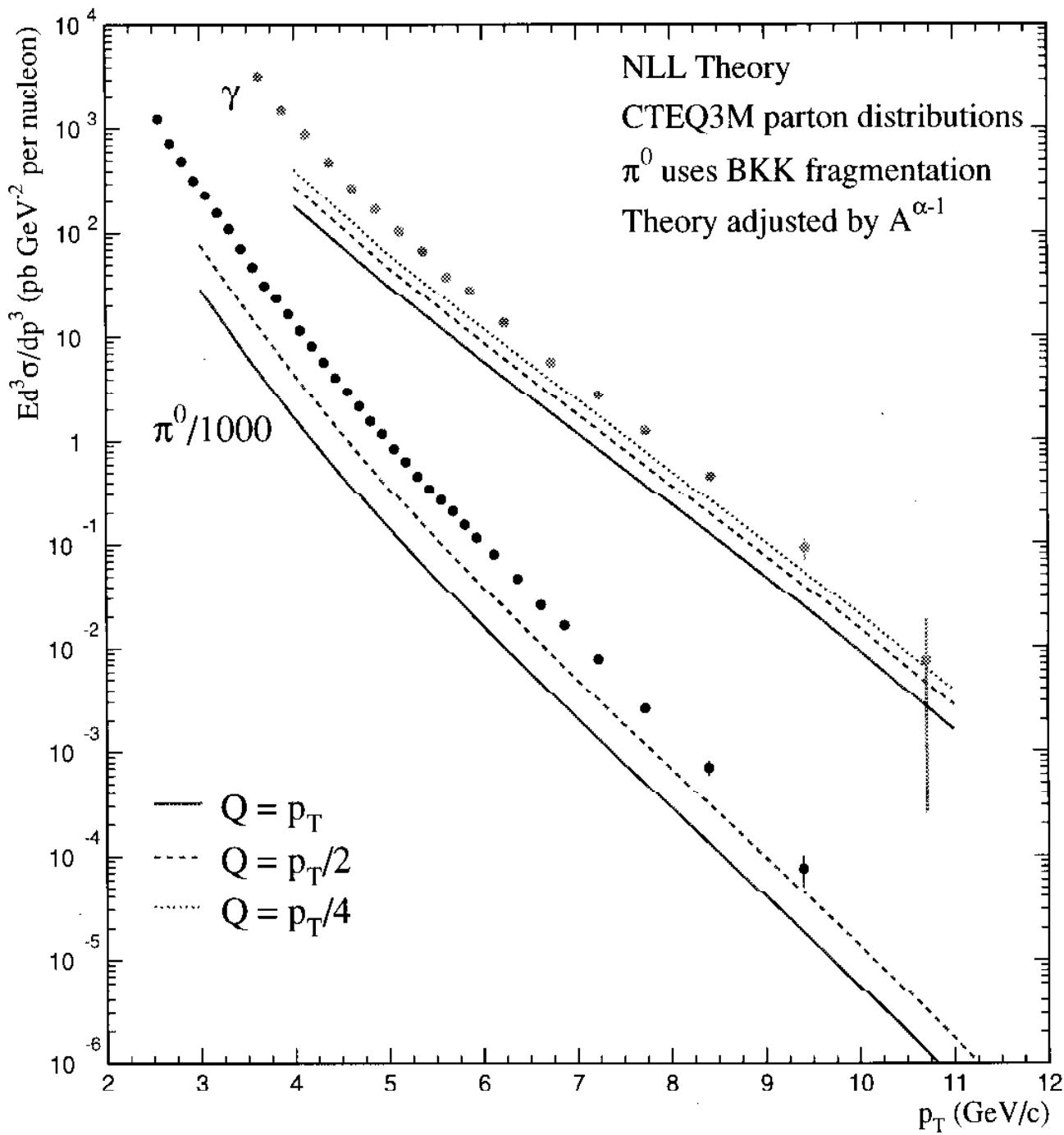
Away Side Fragmentation



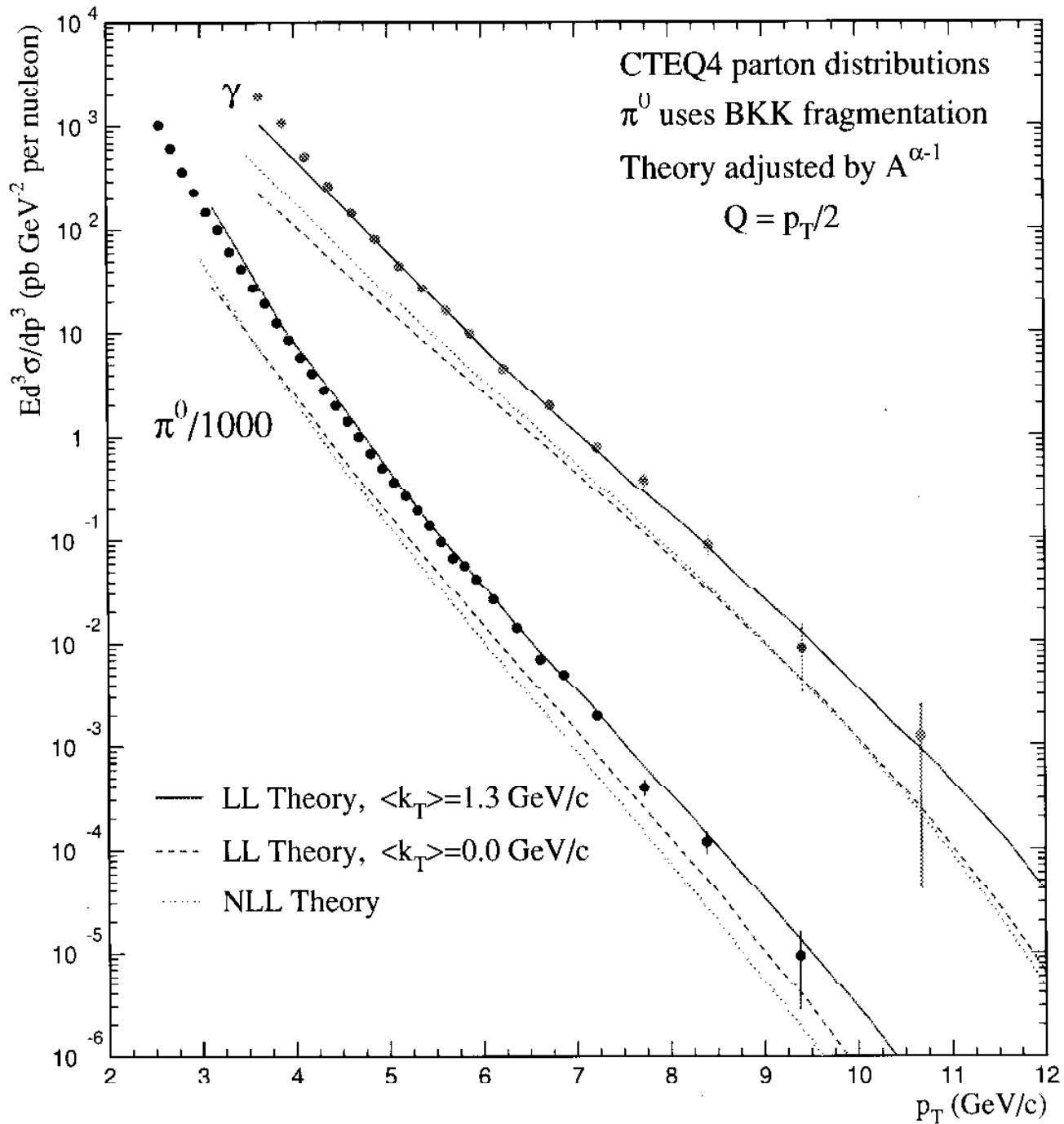




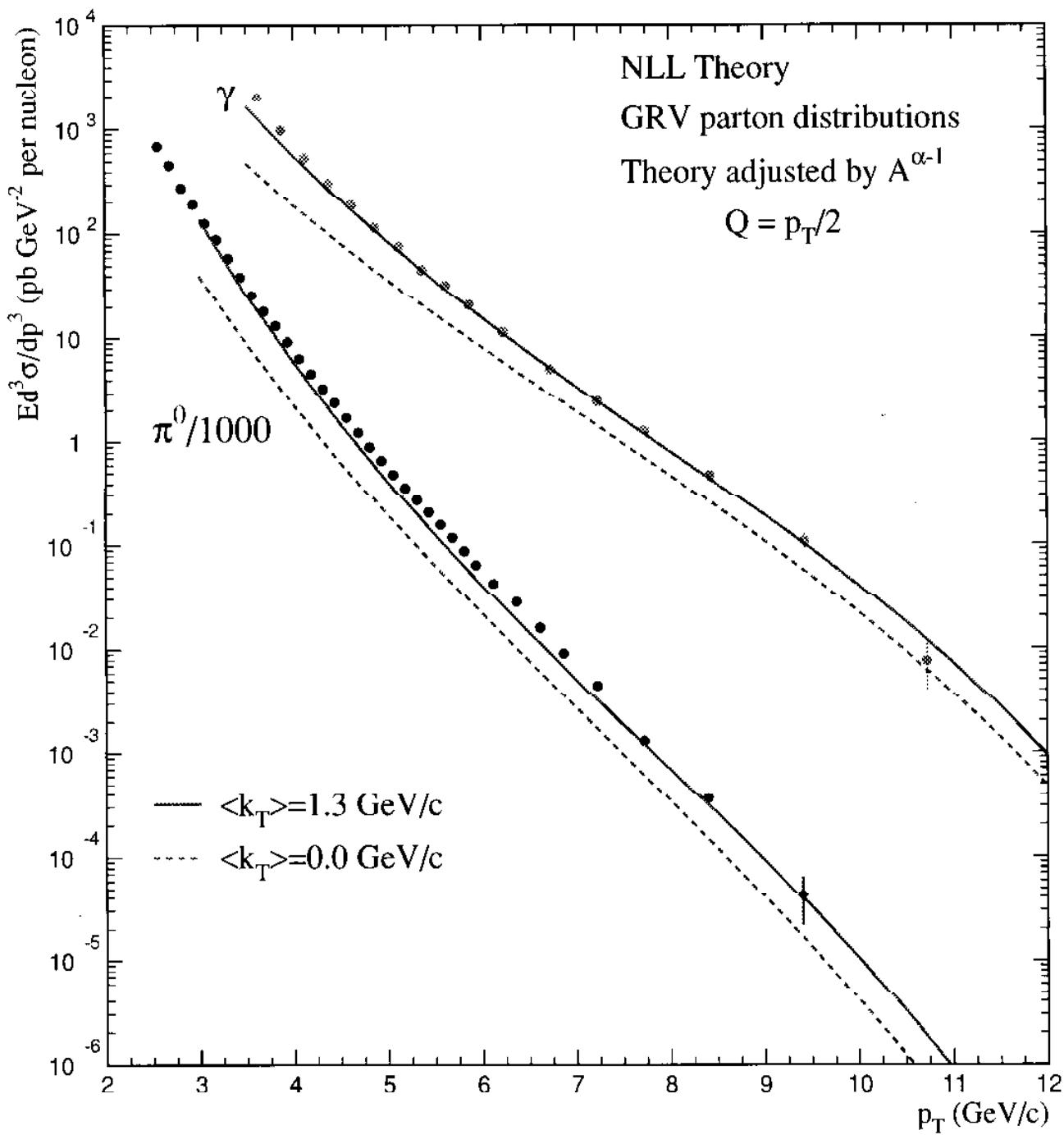
E706 pBe at 800 GeV

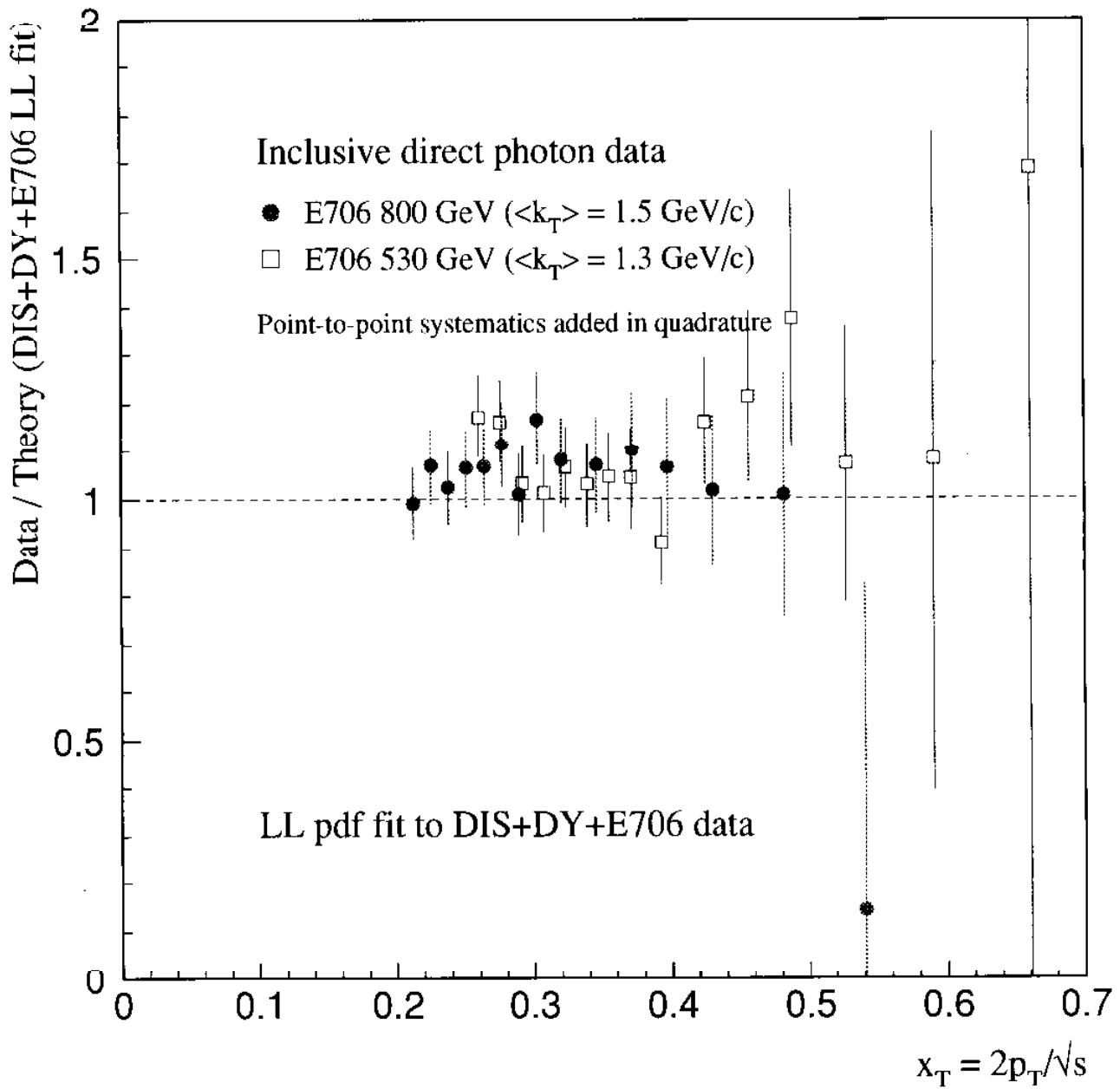


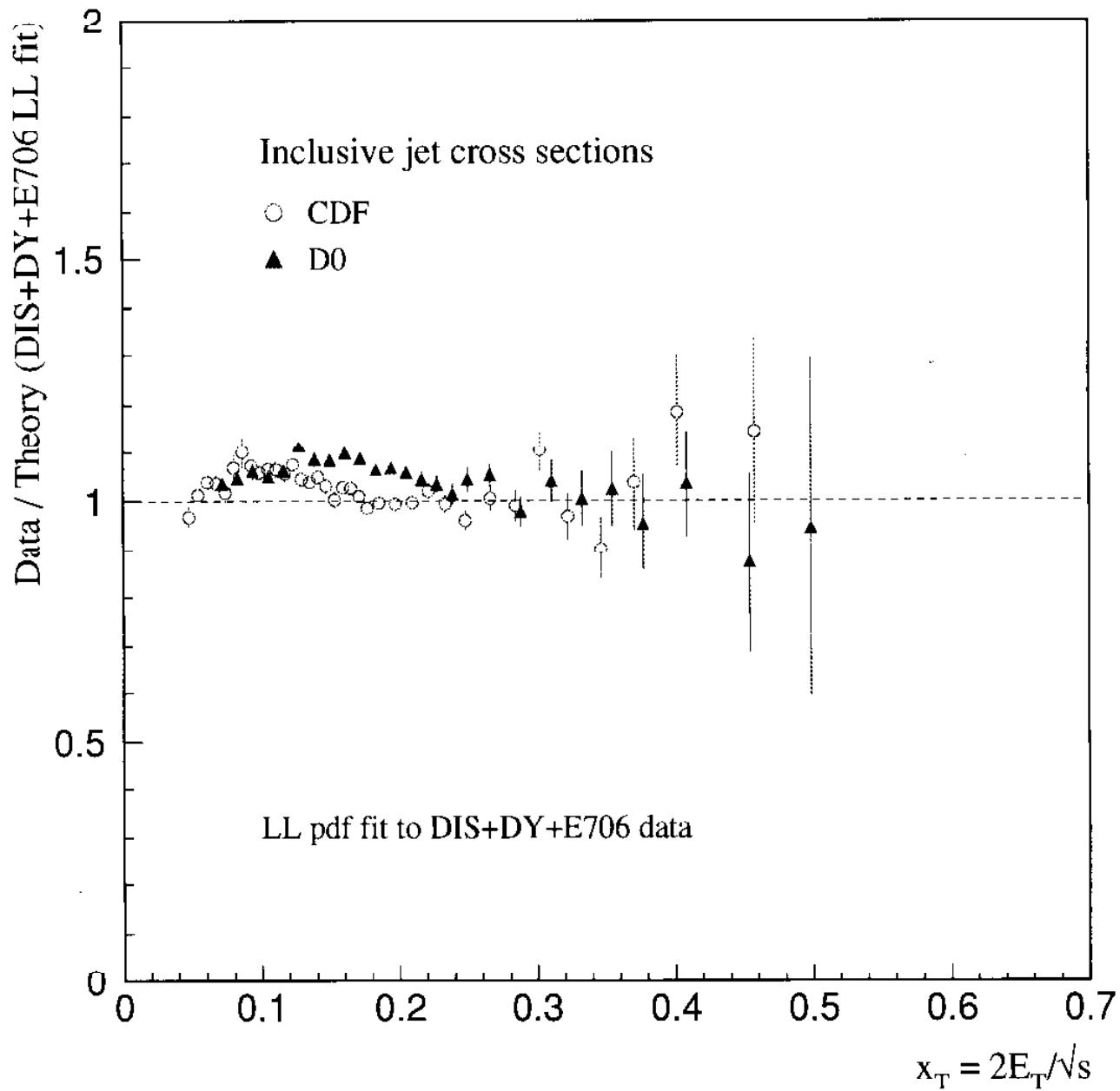
E706 pBe at 530 GeV

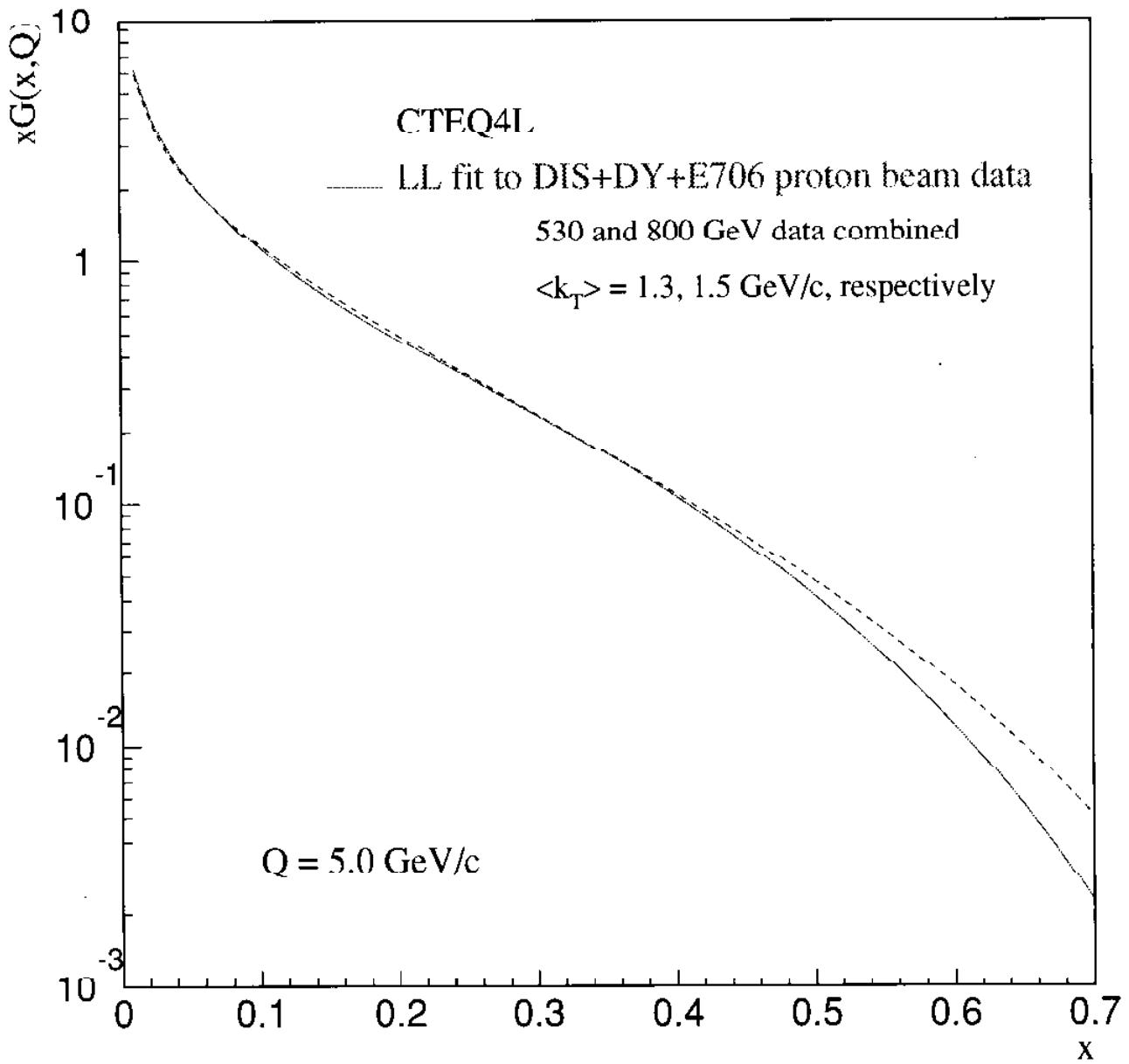


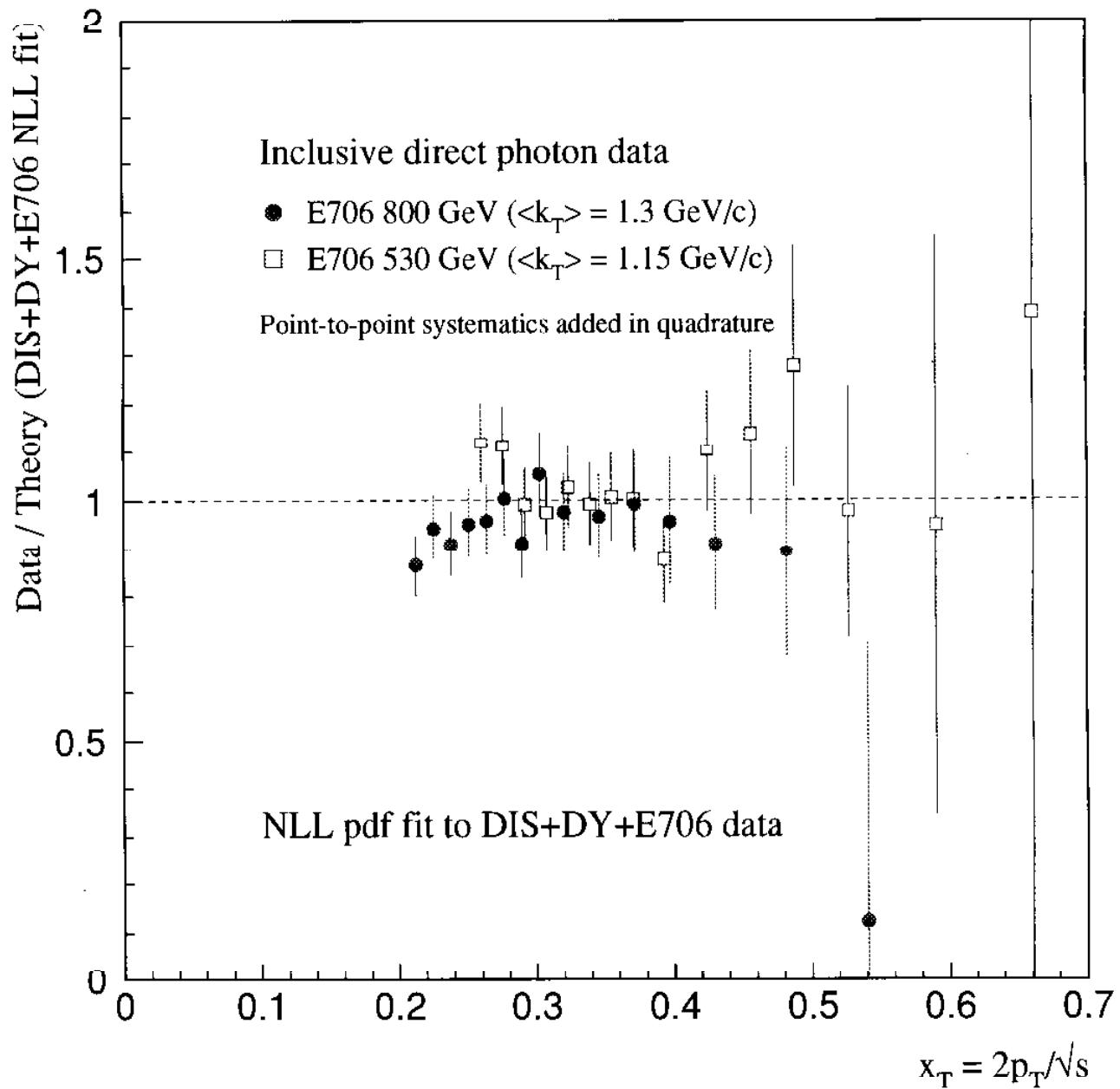
E706 π^- Be at 515 GeV

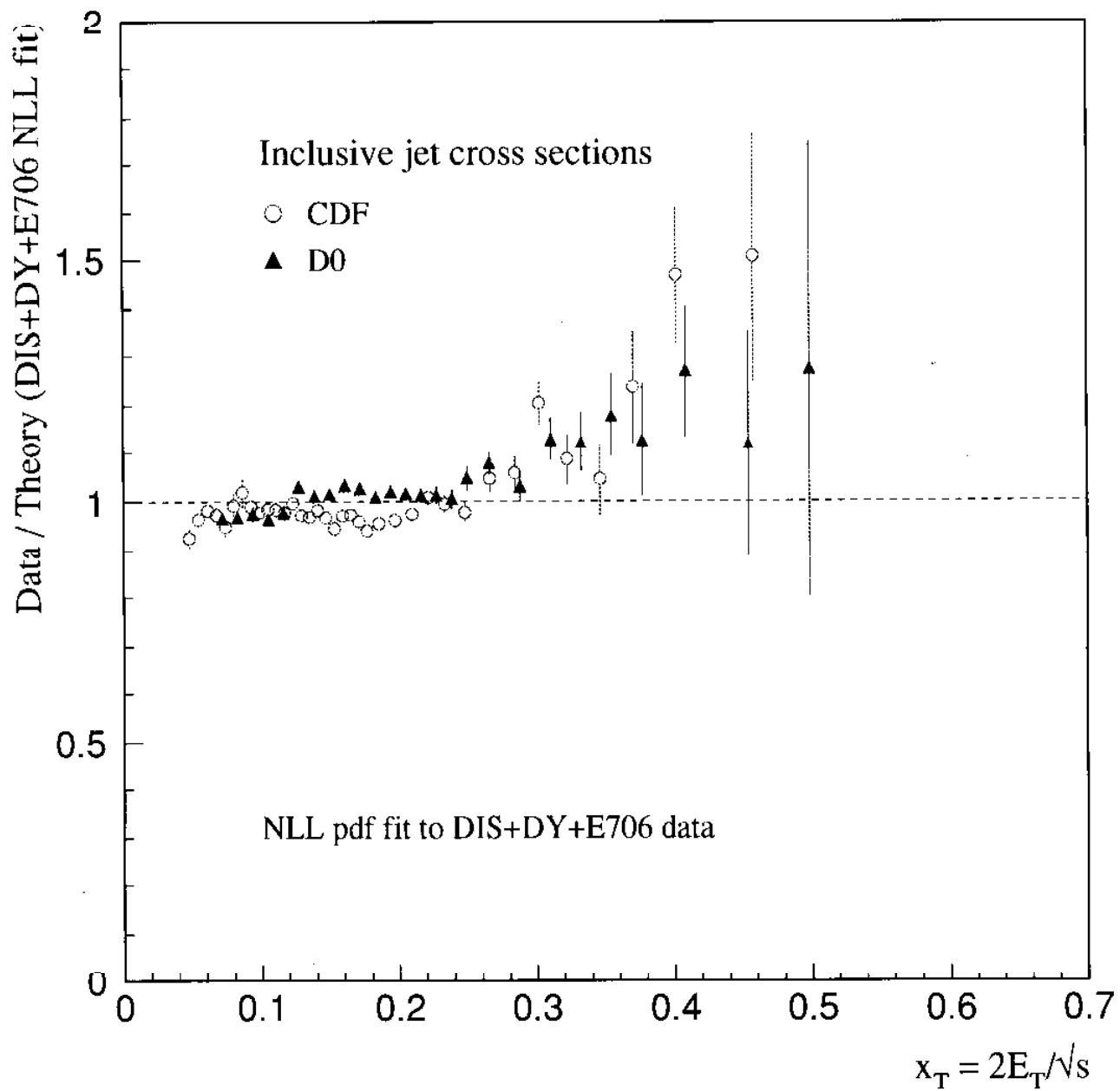


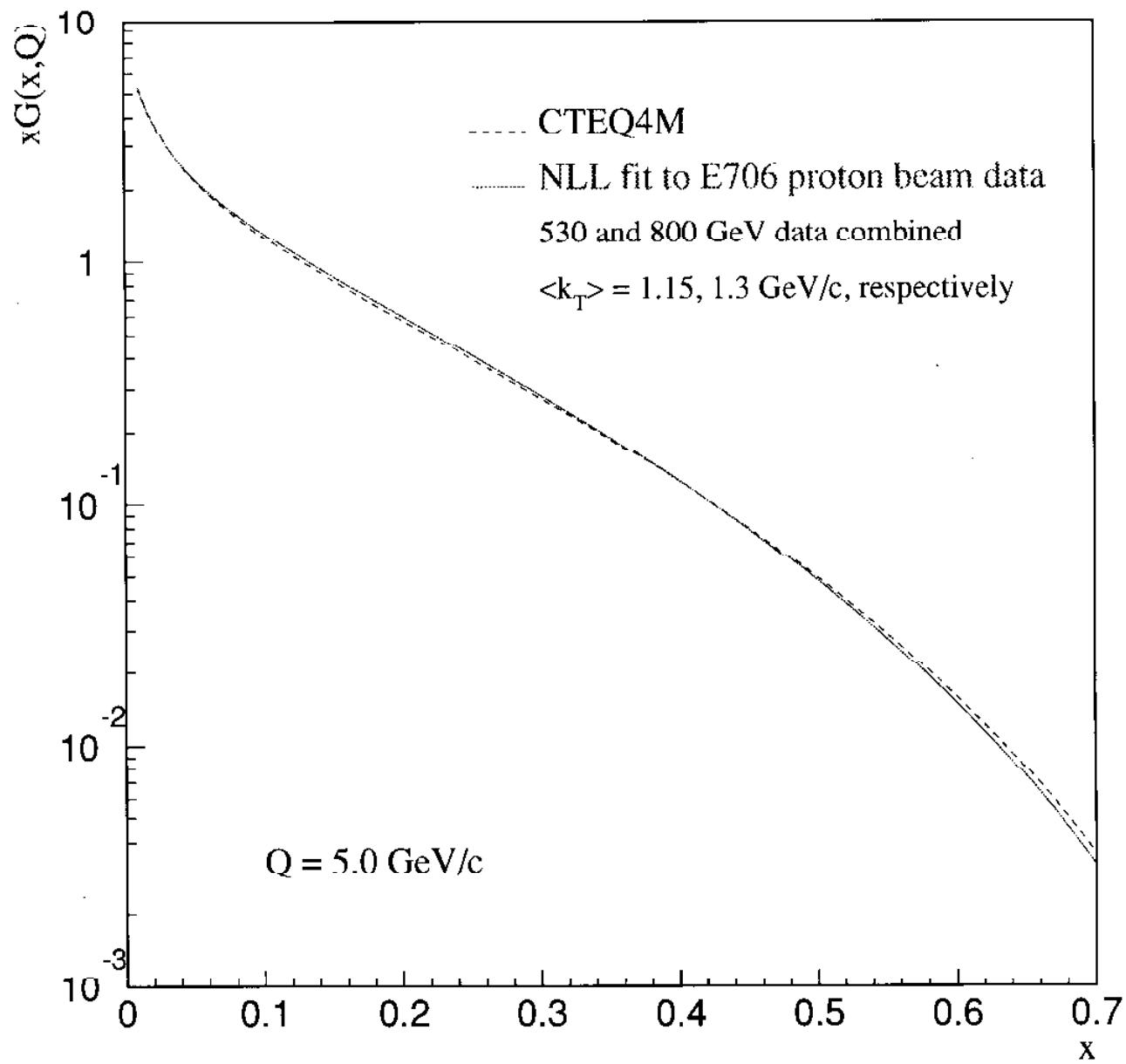












SUMMARY

- Current NLL theory has large scale dependencies and fails to adequately describe the sizes and shapes of inclusive photon and π^0 cross sections.
- Significant k_T effects are observed in kinematic distributions of high-mass pairs.
- Simple implementations of parton k_T in pQCD calculations, using k_T values consistent with observations, provide reasonable descriptions of cross section sizes and shapes.
- CTEQ-style pdf fits to DIS, DY and E706 direct photon data yield a gluon distribution that is consistent with the Tevatron collider inclusive jet cross sections, and similar to CTEQ4 results.
- High-statistics direct photon data from Fermilab E706 is sensitive to the gluon distribution at medium and large x values. Better theoretical understanding of soft gluon effects in inclusive direct photon production would clearly benefit global determinations of $G(x)$.

We thank the CTEQ collaboration for helping us
use our data to study the gluon distribution.